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Thesis Manual Approval Sheet

INTEGRATING COMPUTERIZED VIRTUAL REALITY WITH TRADITIONAL METHODS OF TEACHING SKULL ANATOMY

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DISCLAIMER STATEMENT

This work was supported by the Uniformed Services University of the Health Sciences Protocol No. T061CJ-01. The opinions or assertions contained herein are the private opinions of the authors and are not to be construed as official or reflecting the views of the Department of Defense or the Uniformed Services University of the Health Sciences.

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“Integrating Computerized Virtual Reality with Traditional Methods of Teaching Skull

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Title: INTEGRATING COMPUTERIZED VIRTUAL REALITY WITH TRADITIONAL METHODS OF TEACHING SKULL ANATOMY

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Introduction: The continuing education of health care providers is reliant on recently developed and emerging technological advances such as Virtual Reality (VR). While VR has been evaluated in other areas of teaching the effectiveness of VR to improve anatomical education is minimal.

Methods: The project was a descriptive, evaluative study that compared the benefit of using VR in conjunction with a traditional anatomy lecture to traditional anatomy lecture alone. A convenience sample of 18 USU GSN students was used. Outcomes were measured on the differences between a twenty item pre-test measured baseline knowledge and compared with a similar post-test after completing their skull anatomy learning module. Comparison of the pre and post-test scores was completed using paired t-test to determine the improvement in scoring after participating in the lesson. Participants' demographics (gender, sex, age, etc) were also collected to provide descriptive data.

RESULTS: Data were entered and analyzed using SPSS 10.0 computer program. The mean for the pretest score was 12.39 and the mean for the posttest score was 16.83. Using a paired t-test, the difference for the group between the pre-test and post-test resulted in $t = -7.607$, $p < .0001$. The resulting confidence interval for the mean difference between the two tests was -5.68 to -3.21 .

CONCLUSION: The results were statistically significant, demonstrating that VR did improve the learning experience. Additionally, the satisfaction questionnaire showed that students preferred having the VR augmentation in there learning experience.

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SCHOLARLY PROJECT REPORT TITLE PAGE

**INTEGRATING COMPUTERIZED VIRTUAL REALITY WITH TRADITIONAL
METHODS OF TEACHING SKULL ANATOMY**

By

KARLA MARIE ATCHLEY, RN, BSN, CAPTAIN, USAF, NC

BRUCE DOUGLAS TODD, RN, BSN, CAPTAIN, USAF, NC

SCHOLARLY PROCECT REPORT

Presented to the Graduate School of Nursing Faculty of

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Degree of

MASTER OF SCIENCE

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December 2002

DEDICATION

To the most important people in our lives we dedicate the creation of this project.

Without their love, encouragement, and support the attainment of a dream and the creation of this would not have been possible.

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Running head: VIRTUAL REALITY

Integrating Computerized Virtual Reality with Traditional

Methods of Teaching Skull Anatomy

Capt Karla Atchley, Capt Bruce Todd,

Uniformed Services University

Integrating Computerized Virtual Reality with Traditional Methods of Teaching Skull Anatomy

Chapter One - Introduction

Background

Advances in technology have dramatically altered human culture. Both in the workplace and at home, new inventions and ideas improve the way we live. This is especially true in the field of medicine. Technological advances made in the past several decades have had an enormous impact on how we diagnose and treat diseases and injuries. Equally important is the continuing education of health care providers. Without continued improvement in training and education to match the parallel advances in other areas, health care providers would not be able to deliver adequate care, despite the availability of new technological tools.

One technological area that holds potential value for medical education is Virtual Reality (VR). Virtual Reality employs the latest in computer technology to more consistently and effectively train health care providers, such as physicians and advanced practice nurses.

Currently, VR is being viewed as a supplement to the current teaching methods by providing a new teaching medium. VR could however prove to be extremely valuable in areas such as anatomical education, where the human body could be visualized in a three dimensional manner without use of standard cadaver dissection procedures.

The use of virtual reality technology as an adjunct to traditional anatomy teaching styles has already proved to be useful in various professions, including medical education. The benefits of VR in anatomy education may extend to advanced practice nursing programs that incorporate anatomy education as part of their curriculum. Improving the education of healthcare workers, including advanced practice nurses, may lead to improved clinical, diagnostic, and examination skills and ultimately lead to a higher quality of patient care.

Purpose of the Study

The purpose of this study was to assess the benefits of using virtual reality as an adjunct to traditional methods of teaching in anatomy education. The study measured whether or not an individual can acquire a better understanding of anatomical structures by being exposed to a "virtual" learning environment presented in a VR teaching

lesson. The VR lesson involved the identification of various bones of the human skull, spatial relationships of the bones and brain, and select clinical presentations.

The effectiveness of the skull VR lesson was measured utilizing a specifically designed pre and post-test. The pre-test was administered to the study participants prior to receiving the skull VR lesson. After each participant had equal time experiencing the VR lesson, the post-test was administered and the results of the test were analyzed for statistical relevance.

Hypothesis

The hypothesis for this study was that virtual reality could effectively increase the level of knowledge about anatomical structures, specifically the structure of the human skull.

Theoretical Framework

Utilizing the Educational Evaluation Research Model (EERM) developed by Holzemer in 1988, this study evaluated the effects of the VR teaching lesson. The EERM model was developed to allow researchers to better evaluate educational applications by comparing key elements of curriculum development and system theory. By applying the

framework proposed in Holzmer's model this study attempted to link the outcome of the skull VR lesson to relevant theoretical knowledge. By comparing the outcome of both the pre and post-tests a conclusion might be generated of whether or not computerized virtual reality lesson about the human skull is an effective tool in anatomy education. The simulator experience was also evaluated by a Likert scale evaluation in conjunction with open ended questions to capture to participants appraisal of their individual experiences.

Definitions

Conceptual variables of this study included the process of identifying the effectiveness of this computerized virtual reality anatomy lesson of the skull. The effectiveness of this study's variables' was measured utilizing pre and post-tests to determine how much was learned by the participants taking part in the study.

Operational variables for this study included the delivery of a computerized virtual reality lesson about the skull presented at an individual computer console equipped with VR technology. This virtual reality lesson utilized the Human VisualizeR computer program displayed at a computer console equipped with VR instruments such as data

gloves, goggles, etc.... The sample group for this study consisted of first year graduate nursing students enrolled at the Uniformed Services University (USU) in Bethesda, Maryland. The VR lesson for the skull was developed at the University of California in San Diego, California with USU faculty. Appropriate pre and post-tests were developed based upon the information presented in the VR lesson. The Likert scale evaluation as well as open ended questions were utilized to evaluate each participants opinion of their experience.

Assumptions and Limitations

A major assumption of this study was that VR could be utilized as an effective teaching tool in anatomy education. Other assumptions of this study included the idea that the pre and post-tests administered to each of the study participants would be a valid measure of the level of knowledge gained from the VR lesson and that the sample size of subjects in the study was large enough to draw an accurate conclusion about a larger population.

The limitations of this study were the overall effectiveness of the VR lesson, the validity and effectiveness of the pre and post-test given to the study participants. An additional limitation was that the

requirement for successful delivering the VR lesson relied heavily on a working interface between the study participant and the VR equipped computer. Problems such as software or hardware malfunctions could have limited the effectiveness of the VR lesson; thus having a negative impact on the results of the post-test and/or the study questionnaire.

Limitations relating to the pre and post-tests could arise if the tests do not correspond well with the information presented in the skull. Questions on either the pre or post-tests could have been viewed as being too difficult or too simple in relation to the data presented in the VR lesson.

The final possible limitation of this study could have been related to the sample population. The participants of this study consisted of a convenience sample of USU students. A more representative sample could have included students from other universities, non-military students, and / or students with non-medical education backgrounds. The assessment survey could have been presented in a leading manner, perhaps rephrasing some of the open ended questions could have resulted in different findings.

Chapter Two – Review of Literature

History of Virtual Reality

Throughout history, humans have attempted to enhance their environment either for artistic purpose or to facilitate the passage of knowledge (Olsen, 1997). Early in man's history stories were told around communal fires to entertain the listener and create a "picture" in his mind. Eventually, mankind evolved socially and created other means of communication through paintings and sculptures.

Continued advancement in technology led to the discovery of black and white photography in the early 1800's. Once again humans strove to improve on this technology leading to the development of color pictures and eventually movies.

In the 1940's the first computers were developed. These computers were simple "black boxes" constructed of numerous gears and were used to perform only the most basic mathematical calculations. Unfortunately, these computers were slow at processing information and required a considerable amount manual input. During the 1950's, continued advancements in technology gave way to the creation of computers with vacuum tubes. These proved to

be faster and more accurate, requiring less manual labor than their predecessors. However, the problem with this type of computer was the huge amount of space necessary to house it and the enormous amount of electricity required to run it (Olsen, 1997).

According to Olsen (1997), one definition that has been used to describe 'virtual reality' is the creation of computer graphics to form an illusionary reality. It was not until the late 1950's that a recognizable form of this "illusionary reality" began to evolve. The United States Navy pioneered the development of VR by creating flight simulators. Through the use of video cameras and computers, they would circumnavigate over scaled models of landscape and project these captured images onto a screen located in front of the pilot.

Later in 1960, Morton Helig utilized this knowledge and created what could be called the first true virtual reality machine. By combining a binocular viewing screen with a motorcycle, fan, stereo headphones, and olfactory sensations, Helig constructed what he called the 'sensorama' (Olsen, 1997).

Technology continued to progress over the next few years providing innovations such as the World Wide Web, heads up displays, and three dimensional goggles. While

all of the aforementioned devices were important in producing and controlling VR, the most significant advancement came with the invention of the "data glove" by Thomas Zimmerman in 1980 (Olsen, 1997). The data glove is a device that allows the user to grasp an item in a virtual environment without the use of a keyboard or mouse, while providing a tactile or "feeling" feedback to the wearer.

It is this capability to control the virtual environment in a method that is familiar in the real world that has truly improved the value and experience of VR. Now instead of just watching a movie or an object on the computer screen, individuals may enter into a virtual environment (VE) and explore it while using "visual, aural, and haptic (touching) senses" (Hoffmann and Vu, 1997).

One of the more recent creations that was used in this study is a software package called Anatomic Visualizer. This program "provides a virtual dissection room in which students and faculty can directly interact with three dimensional (3D) models and concurrently access supporting curricular materials" (Rigamonti, Bryant, Bustos, Moore, and Hoffman, 1998).

The Anatomic Visualizer is a software package designed specifically for the purpose of teaching anatomy. Features of this program include the ability to display information

such as magnetic resonance imaging (MRI's), computerized topography scans (CT scans), pathology images, surgical videos, study guides, and lesson plans onto a screen. It also allows for the instructor to build descriptive text and virtual exams into the learning models and have them presented in an organized and progressive manner. This allows for key concepts that require an understanding of 3D structures and their spatial relationships to be enhanced.

Finally, to make this program even more effective to the learner, the creator's have incorporated valuable tools such as the ability to "change opacity or size, dynamically create cross sectional views using a clipping plane, measure size and distance with a virtual ruler, mark structures with a flag, identify structures using a probe, and draw lines and simple objects using a SpaceDraw tool" (Rigamonti, et al, 1998). It is the premise of this study that this type of program may enhance and improve the learning experience.

Educational Applications of Virtual Reality

As educators continue to search for more effective ways to teach students, methods of education continue to change. Throughout the last decade, VR has been explored by the educator as a tool to enhance student learning

abilities. Different uses of VR in the medical field such as a measure of nursing students' decision-making skills and assessment of stoma care in continuing education have already been done (Koyama, Holzemer, Kaharu and Watanave, 1996). The primary aspect has involved the use of VR in situations where medical personnel are attempting to perfect a skill that will be utilized in situations when the comfort of the patient is to be considered as well as protecting the patient from the jeopardy of injury or death. The learned skill of the provider is often needed in times of high stress and many times the provider cannot simply stop and wait for the help of someone more experienced.

VR has been used in the operating room to improve skill of both the surgeon and the anesthesia provider. The goal of VR is also to prepare providers in a manner that will enable them to provide emergency care. VR allows the provider to simulate emergency procedures on VR trauma casualty victims, thus leading to a better outcome. These trauma cases often do not present themselves to all providers on a regular basis, but when they do, the provider needs to feel confident in their ability to provide outstanding medical care without hesitation.

Military medical personnel face yet another challenge since they can be called at a moments notice to go into a battlefield situation. Providers typically lack the opportunity to utilize skills of trauma management, as well as caring for the typical wartime casualty in our present peacetime situations (Willy, Sterk, Schwarz and Gerngross, 1998). The use of VR to create wartime situations can eliminate this disadvantage.

VR can also provide an evaluative measurement of student comprehension. The educators who are responsible for imparting the basic knowledge will take a real interest in a measuring tool that will allow them to know how they are meeting their students' needs. Furthermore, not only does VR allow the educator to evaluate the learner, but their own individual method of teaching as well.

It is well known that the optimal learning environment can vary according to individual students. Students may prefer the visual learning method, but then others benefit from auditory reinforcement and yet others may benefit most with the use of psychomotor skills. VR provides multiple alternatives to best suit the student's current needs. VR provides a consistent anatomical environment that allows the student to access clinically related topics and scenarios, such as surgery and pathophysiology to specific

anatomy. Computer assisted anatomical learning has been implemented on an individual basis and in a classroom setting. VR is also proving advantageous for military "mission rehearsals" (Satava and Jones, 1997). Using multiple senses to enhance the learning experience provides a comprehension of the material that best prepares students in these highly detailed, complex fields where mistakes can be made while learning and avoided at all cost in actual scenarios.

VR has the ability to be a valuable supplement to classroom lectures in a manner in which students and instructors benefit. The student's need for continual feedback during dissection is not a realistic goal during an anatomy course. This could now be a problem of the past. Through the availability of 3D dissection, students would have their own instructor in the form of computer feedback. In addition, virtual dissection will eliminate the inconsistencies of individual human cadavers. Medical professionals would have the opportunity to recognize the normal anatomy before they confront randomly discovered abnormalities.

Many medical schools currently use slices of frozen cadavers that are cut by band saws and then encased in Lucite for gross anatomy practical exam material. These

slices are limited to anatomical identification in a 2D setting. VR not only provides a 3D element but can also provide avenues to integrate these slices to other relevant medical curriculum such as radiography.

VR is an educational tool with broad applications. "VR-based procedural and surgical simulations, often compared with flight simulators in aviation, hold significant promise for revolutionizing medical training" (Hoffman and Dzung, 1997, p. 1076). These new systems promise to make broad-based training experiences available for students at all levels, without the risks and ethical concerns typically associated with using animal and human subjects. Medical students could acquire proficiency and gain confidence in their ability to perform a wide variety of techniques long before they need to use them clinically. Surgical residents could rehearse and refine operative procedures using an unlimited pool of virtual patients (Hoffman, 1997). It is easy to imagine the current and potential benefit of VR in the surgical field. With the increased use of endoscopic surgery for various illness or injury, providing quicker recovery and shorter hospital stay, these surgical skills will be coveted.

Anesthesia curricula are now utilizing computer-assisted instruction (CAI), according to a survey completed

by Burnette et al in 1997. CAI is used by 18% (n=78) of nurse anesthesia programs, with many more planning to incorporate this teaching technique. In the summer of 2000 the Uniformed Services University Nurse Anesthesia program first utilized VR in the classroom setting. VR was used in assisting the 3D visualization of the lungs, skull, inner ear and innervation of the heart. Using the Visualizer software the instructor was able to manipulate the structure moving it in all directions, make surface structures transparent and pull out organs for closer examination.

Other applications for VR include training for the military battlefield, combat casualty care, and civilian disaster management. "The power of using 'mission rehearsal' for military combat in a VR environment was proven by the training that resulted in the overwhelming success of the Gulf War" (Satava and Jones, 1997, p. 139).

The opportunity for many individuals to occupy the same VR environment allows for interactive networking. This integrated scenario offers something that is impossible today-the ability to locate, triage, and evacuate a casualty in a single continuous simulation. This allows various participants to interact during the mission rehearsal. This would eliminate the expense of field

exercises, the wounding of animals, or the mobilization of ambulances and helicopters. Also, the training can be repeated until perfected (Satava and Jones, 1997). "The sense of touch, force feedback ... will be able to provide a wound that a medic can observe, touch, use surgical instruments to debride, control hemorrhage, and bandage" (Satava and Jones, 1997, p. 141). VR can also provide damaged organs that must be operated.

"The realism of simulation is related directly to the multiple senses incorporated into the simulation. The visual and auditory inputs are relatively sophisticated; however, the sense of touch is still primitive. The senses of olfaction and taste have not been implemented as yet. The importance of olfaction to the sense of realism is still unknown" (Satava and Jones, 1997, p. 143).

The design of VR provides learning avenues that can be consistent and repetitive. This allows the individual student or instructor to create an environment that is best suited for the situation. VR may also provide clinical correlations at the touch of a computer button. The field of VR is broader than first expected. VR is currently utilized the most in surgery, anatomy, and military "mission rehearsal". Use of the senses promises to provide

further realism to optimize the students learning experience.

Current and Future Applications of Virtual Reality

In the 21st century, VR will play an important and significant role in the realm of medical education. VR provides a risk free tool for assisting students as they maneuver through the myriad of systems and structures of human anatomy. The global implications of VR are expanding with the use of the Internet. A 3-D image can transcend the linguistic-descriptive barriers that currently plague clinicians and scientists in their comparative research. Students can benefit exponentially as databases have Web linkage capabilities. The use of VR seems to be limited only by one's imagination and the speed and development of user-friendly computer systems. Some of the current and future areas of most interest discussed by a myriad of articles include surgical simulation, anatomy instruction, anatomy testing, exposure to anatomical variations, animation of body and organ kinetics and World Wide Web access.

Fascinating new developments in VR include what is called "immersive" VR (Hoffman, 1997). This type of VR creates a sense of "cognitive presence" by providing users

with a stereoscopic visual display that changes in response to head and eye movements. The equipment for this type of VR includes a helmet like display, position-tracking equipment and specially designed movement gloves. This newer type of VR is in stark contrast to "non-immersive" VR (Hoffman, 1997). In the latter, the user views a computer screen and manipulates the program using a mouse or joystick. Immersive VR is potentially more beneficial as a learning tool than non-immersive VR in that it allows the user to physically manipulate the environment while integrating depth and spatial dimensions. "...VR can be used to create knowledge-building experiences that facilitate the comprehension of 3-D subjects e.g. anatomy" (Hoffman, 1997, p. 1077).

An example of immersive VR is the Anatomic Visualizer. Currently the Anatomic Visualizer is being further developed by the University of California at San Diego (UCSD) to provide an immersive VR workspace where users are "free" to dissect 3D internal structures. The program also allows for access to supporting explanatory models, diagnostic images and surgical videos, and is currently being used in conjunction with UCSD's pre-clinical anatomy curriculum.

One of the most important new applications of VR is called the Visible Human Project of the National Library of Medicine (Bean, 2000). This program provides the most detailed database for 3-D male and female anatomies in existence. In the future, other human anatomical variation databases will be added such as children and subjects of various ages with congenital anomalies. Using this new 3-D model, students will be able to repeatedly dissect different areas of the body as well as surgically correct displayed problems. It will be possible to manipulate the size of a particular organ in order to improve visualization of minute structures or even view its histology. VR based programs "will allow users to investigate structures in ways not possible in the real world" (Bean, 1998).

VR development is not restricted to the United States alone. In Sweden, at The Goteborg University, a new virtual 3-D brain application has been developed. Using tissue slicing from high-resolution photographs, a PC friendly, simplified VR system has been created to facilitate visualization of brain concepts for the University's neuroanatomy curriculum (Hoffman, 1997).

At Columbia University, designers are working on a way to integrate a system that further aids the user in the

comprehension of anatomical structures and abstract bio-systems. The proposed program is referred to as the Symbolic and Spatial Knowledge Model (Bean, 1998). This particular program provides links to a global network. This system has a "modular knowledge base of anatomy, capable of accommodating different perspectives of the content and of providing linkages within and among both local and global resources" (Bean, 2000). The program, while complete and independent, can easily incorporate and integrate other sites. This linkage will be possible via Web-based interfaces on the Internet. This innovative program will combine different perspectives of anatomy with respect to curriculum.

It has also been noted that different aspects of the medical sciences require a program that can differ in the directive of the application. "For example, clinical anatomy traditionally uses a regional perspective while the basic sciences require one more oriented toward functional systems" (Bean, 2000). The format of the program employs a collection of 3D surface-based anatomical structures displayed by a 3D box.

Each scene contains a subset of anatomical structures whose spatial locations intersect the scene box. The user can then dissect the various layers of these anatomical

subsets or examine them as a complete entity. The parameters of this program are exceptionally broad based in that it not only provides the learning advantages of a 3D model, but it can also integrate other outside web linkages, giving the user a more complete system than the traditional VR. One can also infer that, because of its Internet capabilities, this program provides an optimal avenue for easy technological reprogramming in the constantly changing world of medicine.

The preceding is noteworthy in that one of the fundamental criticisms of VR is that the replacement of expensive VR systems in response to technological updates was not cost effective for teaching facilities.

Researchers at University of Washington in Seattle are working on a program similar to the Symbolic and Spatial Knowledge Model. The Seattle system is known as the Digital Anatomist Dynamic Scene Generator (DADSG) (Brinkley, 2000). This project also seeks to find a way to integrate the print library of human anatomy with a Web-based structural anatomical image library into one unified teaching program. The authors feel that prior attempts towards this unification were flawed in that they did not provide "a comprehensive symbolic knowledge base of

anatomical terms and relationships that gave meaning to the images" (Brinkley, 2000).

Previous programs also failed in that the datasets were unsuccessful in associating each extracted structure with a name from the knowledge base. The directive of the Web based DADSG is to render the images on the Digital Anatomist Foundation Model (DAFM), a comprehensive VR library, onto a fast server. The transported 3D pictures are then sent to a Web browser where the user can navigate and manipulate the various scenes. The authors feel that this program has the potential for many future Internet implications. "Other Web-based applications include structure-based visual access to non-image based biomedical information, thereby bringing us a step closer to the long-term goals of the Visible Human Project" (Brinkley, 2000).

There is an abundance of literature delineating the current and future uses of VR in the medical environment. However, no literature was found regarding comparison studies of traditional medical instructional techniques such as the use of lectures, texts, and dissection to instruction utilizing VR.

Previous literature has categorized the various uses and applications for VR. However, as with all technology today the rapid advancement of new VR based technologies

necessitates coinciding studies that demonstrate the practical applications of these programs (i.e. teaching).

We hope to systematically compare this VR format with currently used traditional methods in order to identify the appropriate role in anatomy education.

With these exciting developments in VR, one can only imagine the possibilities that lie ahead in the future of clinical training. A change from the time-consuming reference library and cadaver lab to an interactive comprehensive VR system is a necessary technological progression. The visual/tactile capacities of VR may not only provide a more effective method of learning for the student but also allow for risk-free digital human forms for a student to dissect, manipulate and repair as many times as necessary. With the plethora of new biotechnologies and surgical methods, a unified accessible world based system is necessitated. VR bridges the information gap that these various idioms present. As VR continues to streamline, the program directives to encompass abstract systems and global Web links, all medical related fields have the potential to be better trained and more knowledgeable than their predecessors were.

Chapter Three - Methodology

Research Design and Procedures

The purpose of this study was to assess the effectiveness of VR to improve anatomical education by acting as a supplement to traditional teaching methods. The study used a descriptive evaluative design. A pre-test and post-test was administered to examine the efficacy of VR as a means of refreshing previously learned anatomical structures and clinical concepts of the skull.

Sample

The sample population consisted of first-year graduate nursing students attending the Uniformed Services University (USU). The class of 2002 participated in the study resulting in a total sample of 18. The total class enrollment was 27; four of the students were directly involved with data collection. With the exception of the four students conducting the study, 78% of the first year students volunteered to participate.

Measurement

Demographic data were collected on age, years of nursing experience, educational level, and gender.

Participants were asked to indicate amount of computer

experience, prior VR experience, level of anatomy education, and level of teaching background. Pre-tests consisted of twenty items identified as key concepts that should have been retained from the student's prior anatomical education.

One principal investigator operated the simulator to minimize the "learning curve" required with the use of the VR equipment. The other principal investigator administered the same test immediately following the VR training experience.

Pre and post-test questions were constructed by the students conducting the research and reviewed by a subject matter expert.

Participants were given an evaluation questionnaire using a Likert scale to rate their subjective viewpoint on the effectiveness of their training. The goal was to see if they believed the use of VR enhanced their ability to retain the concepts, their overall satisfaction with the simulator experience, and the quality of the lesson material.

Protection of human rights

Uniformed Services University of the Health Sciences (USUHS) Investigative Review Board (IRB) approval was obtained before data collection began. The approach to prospective students was initially through an oral presentation prior to the learning experience. This included time for the participants to familiarize themselves with the equipment and ask questions. A written description of the study including time commitment was distributed to the participants.

The principal investigators again described the purpose of the study both before obtaining informed consent and after participants had sufficient time to consider if they wished to participate. Participants were assured of their ability to not participate without fear of any kind of academic consequences. Participants were allowed to drop out of the study at any time. The time commitment required for each student was approximately two hours.

Once informed consent was obtained the participants completed a pre-test, then moved to an adjacent room for a one-hour lecture using a standardized lesson plan with use of the VR skull operated by the principal investigator. Following the lesson, they were offered a break and then

the participants completed both the post-test and satisfaction questionnaire. The process was repeated until all participants completed the research study.

Confidentiality was maintained by assigning identification numbers, which was kept separate from all data forms. Only the research team had access to the secured data.

Data Analysis

SPSS was used to perform a paired t-test comparison of the pre and post-test multiple-choice cognitive exam. The Likert scale was used to describe the satisfaction with the experience based on selective demographics.

Chapter Four- Study Findings

The purpose of this study was to assess the benefits of using virtual reality as an adjunct to traditional methods of teaching in anatomy. This chapter will include the data analysis findings for each question. Each research question is examined and the findings summarized.

Sample, Demographics and Data Collection

The sample consisted of the population of first-year graduate nursing students attending the Uniformed Services University. Volunteers in the class of 2002 participated in the study resulting in an N of 18. A convenience sample obtained as many students as possible with the exception of the four students conducting the study. The mean age of the participants was 35.38 years. The study group consisted of 13 males and 5 female participants. Eleven Family Nurse Practitioner (FNP) and seven Nurse Anesthesia (NA) residents took part in the survey. The participants averaged 8.38 years of nursing experience (Figure 1).

The entire group of eighteen participants had completed an anatomy class in their undergraduate program. In the fall semester of 2000 the GSN class had completed an Anatomy and Physiology class utilizing Virtual Reality. Twelve of the eighteen participants felt that they learned

best by interaction, four by lab experience and two by lecture.

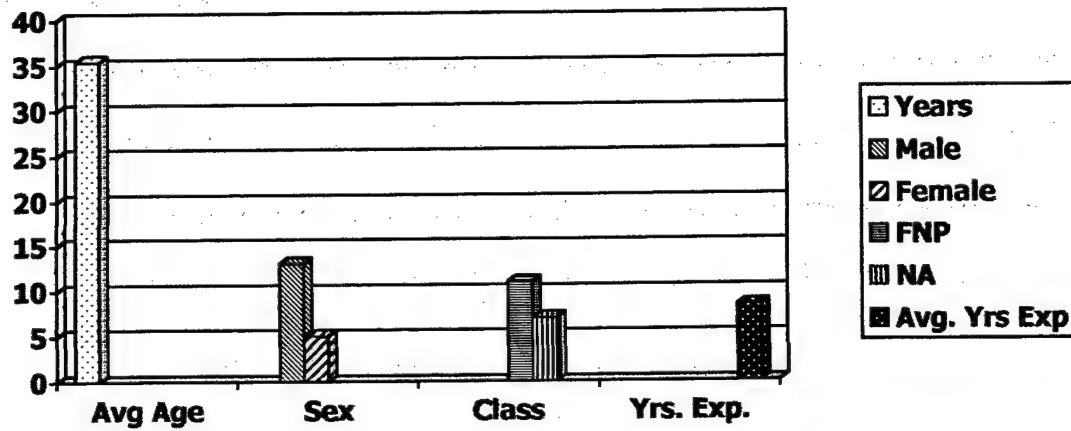


Figure 1: Demographics of the study group

The hypothesis for this study was that virtual reality could effectively increase the level of knowledge about anatomical structures, specifically the structures of the human skull.

SPSS was used to test the significance of the data collected. A Paired t test sample statistic compared two categories, pre/post test number correct and pre/post percentage correct. Paired sample 2-tailed t test revealed a p value of .0008 in evaluating both the number and percentage correct of the twenty items possible (Figure 2).

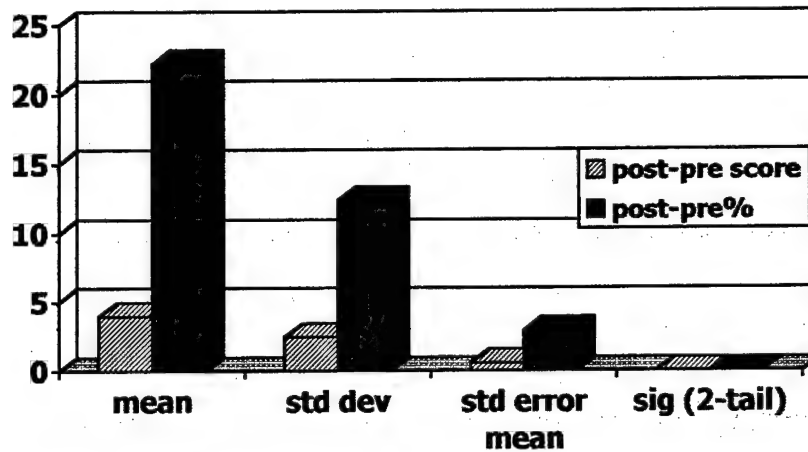


Figure 2: Paired t test sample

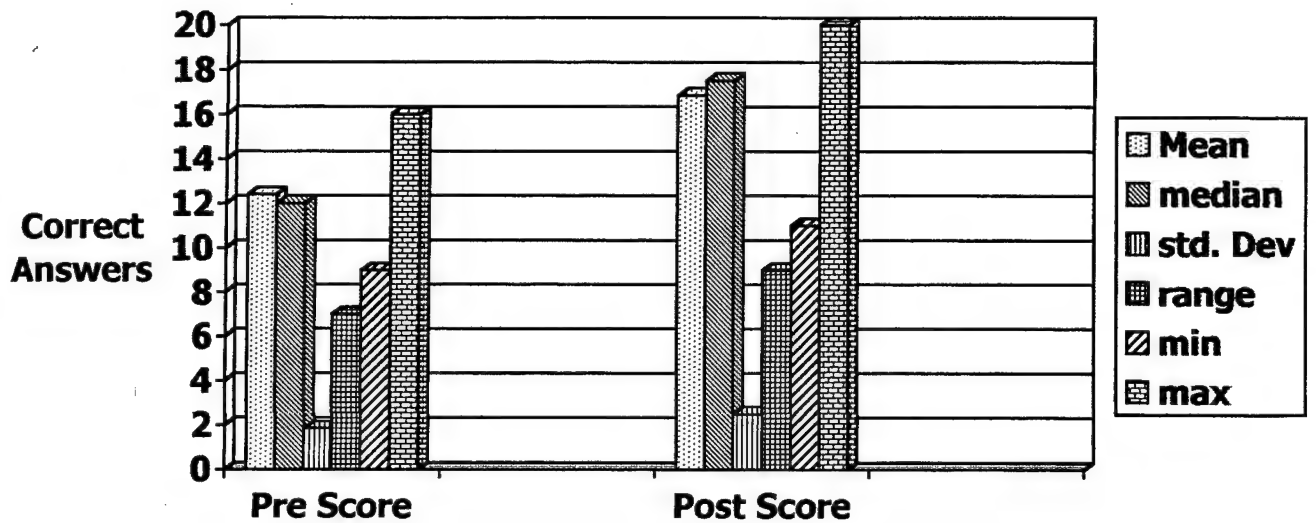
The 18 graduate students who participated in the skull Virtual Reality lesson were divided into nine groups of two students each, in order to limit distraction during the lesson and testing time. The participants completed a pre-test of twenty items followed by a Virtual Reality lesson in skull anatomy. The Virtual Reality lesson was conducted within a 45-minute timeframe and was located in a quiet learning environment. The participants were allowed ample time to review points of particular interest to them. Upon the completion of the VR skull lesson the participants completed the same twenty item multiple choice test as a post-test to analyze knowledge improvement after experiencing Virtual Reality. The number of items correct in the twenty question pre-test reflected a mean of 12.39 with a standard deviation of 1.85. The number correct in the twenty question post-test showed an improvement reflecting a mean of 16.83 with a standard deviation of

2.50 (Figure 3) The percentage score was also evaluated. This reflected a pre-test percentage of 61.94 and an increase in the post-test percentage to 84.17 (Figure 4). The results of the paired t test were $t = -7.607$ and $p = 0.000$, With a difference between the standard error means of 0.15.

In the assessment survey, the entire study group of eighteen noted that this VR experience increased their understanding of the skull anatomy in conjunction with the clinical implications discussed during the VR experience. Ten of the group strongly agreed that they preferred to learn the material in a lecture hall with the VR, six agreed and two were undecided. The last question asked if they would prefer to learn this material in a lecture hall with a conventional didactic lecture. Three strongly agreed, two agreed, four undecided, four disagreed and five strongly disagreed. The spread of results on this question makes it difficult to be sure the question was worded correctly.

The open-ended questions resulted in a primary theme of the most liked aspect of the study was the 3-D visual impact with the ability to take the skull apart for greater understanding of the anatomy. The least liked aspect of the study was that the participants were not able to physically

manipulate the VR image themselves with the haptic gloves
and the fact that the X-rays and MRI's were not



incorporated into the VR program.

Figure 3: Comparison of items correct

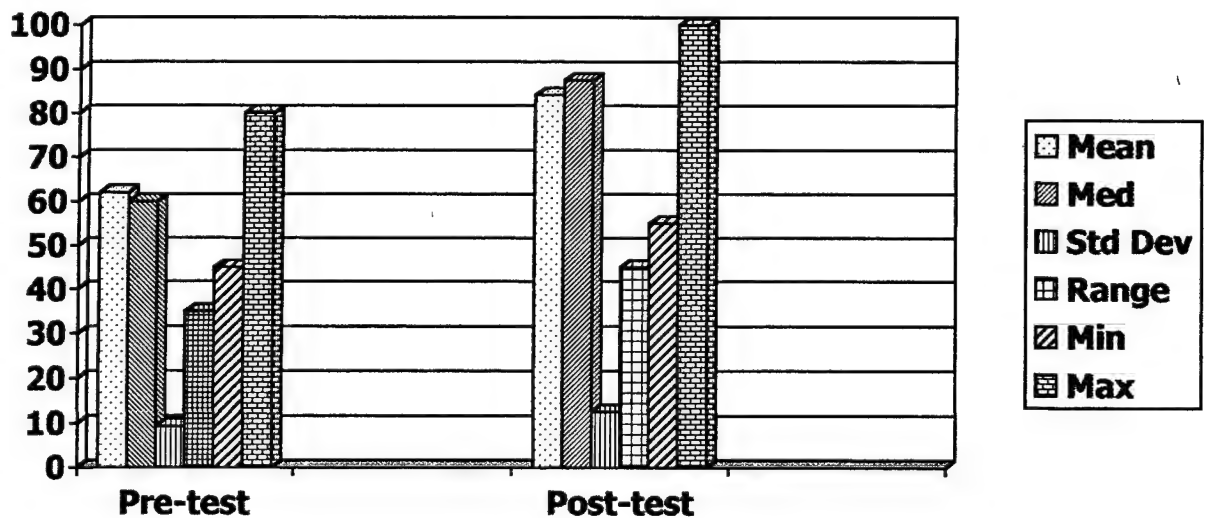


Figure 4: Comparison of percentage correct

Chapter Five- Discussion

The purpose of this study was to assess the benefits of using a virtual reality (VR) simulator for teaching and improving competency in anatomy education.

Virtual Reality evolved as computer graphics in the late 1950's and became recognized as "illusionary reality" (Olson, 1997). Initially, virtual reality was limited to visual interaction. With advancement in technology, the use of VR includes the ability of individuals to enter into a virtual environment and explore it while using "visual, aural, and haptic (touching) senses" (Hoffman and Vu, 1997).

Virtual reality has been used in a variety of educational, training, and entertainment settings. The highly visual and interactive nature of VR has proven to be useful in understanding complex 3D structures and for training in visuospatial tasks (Gorman, Meier and Krummel, 1999).

Currently, virtual reality training simulators offer a more realistic model of common medical procedures such as surgical procedures and dissection, regional anesthesia, endoscopic sinus surgery and training for emergency medical personnel. The potential for training with VR is great,

what was once used for recreation in the past could become a the method of education in the future.

Many studies were found recognizing the benefits of using VR in education. However, literature regarding the comparison of studies between traditional anatomy instruction alone to traditional anatomy instruction with VR was not found at this time in the literature.

Anatomic VisualizeR levels the playing field by giving each student, regardless of individual differences, the same opportunity to maximize his or her anatomic learning experience at his or her own pace and convenience (Rigamonti, Bryant, Bustos, Moore, and Hoffman, 1998). Using the Anatomic VisualizeR, students are able to disassemble and reconstruct spatial anatomic relationships while participating actively in the virtual learning environment.

Implications

This study measured whether or not an individual can acquire a better understanding of anatomical structures by being exposed to a "virtual" learning environment presented in a VR teaching lesson.

VR simulations will become an increasingly important skill with the current trend toward computer-based learning. Students will need to become comfortable

interacting with computer learning modules as adjuncts to classroom lessons.

The availability of web-based anatomy will be an asset to providers who are unable to ask advice from their colleagues as well as providers who are in training. This study was completed as a supplement to education acquired in the anatomy laboratory.

This type of VR learning will also be beneficial to those who have graduated and left the cadaver lab at the university. The person who finds him or herself removed from their colleagues can potentially utilize a program such as VR from anywhere in the world to explore and reexamine the human anatomy at a time that is convenient to their need. The ability to dissect the VR image in layers without destroying the anatomy, to remove and replace parts of the image will clarify the correct anatomical location of individual parts of the body. This field of study is not limited to the skull and will expand as advancements are made in the study of VR.

In comparing the outcomes of both the pre and post-tests a conclusion was shown that computerized virtual reality lessons regarding the human skull was an effective tool in anatomy education. The results identified a pre to post

score improvement when Virtual Reality was utilized as a teaching method.

Further Study Recommendations

Further study of Virtual Reality as a direct comparison to an identical lesson taught in the classroom setting would identify stronger comparisons relating to the ease of duplication.

The ability to generate a Virtual Reality that is more user friendly for first time users is in the hands of the computer programmers skilled in this area. This would enable the students to manipulate the haptic glove themselves instead of a receiving a guided tour by the instructor.

The advancement of preplanned lessons and the equipment improvements will be an asset to future lessons. Comparison of traditional lessons in conjunction with VR lessons to a traditional lecture lesson is a new avenue of study and will require more studies to come to a conclusion. This study group had received a traditional lesson with the adjunct of VR. Further studies comparing two study groups receiving the same traditional lesson, and then later provide VR as an adjunct for part of the group would actually contrast the comparison finding more accurately.

Summary

In summary, this research evaluated the use of VR as an adjunct to traditional teaching methods. The study participants received the traditional lesson including cadaver laboratory in the summer. The following spring the study group participated in this research project.

There were 18 participants in the study. In addition to the numerical test scoring, demographic questionnaires were obtained at the time of participation. The primary finding was that learning with the use of Virtual Reality was preferred to learning the identical anatomy lesson in the traditional classroom setting.

The use of VR in many settings has been studied but the foundation is now being laid in teaching human anatomy with the use of VR. The future is bright in this direction with the current trend in electronics and the increasing ease to access and manipulate the programs from distant locations. The use of Virtual Reality will enhance the study of many topics including anatomy education.

Time Line following proposal approval

[illegible]

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UNIFORMED SERVICES UNIVERSITY OF THE HEALTH SCIENCES

4301 JONES BRIDGE ROAD
BETHESDA, MARYLAND 20814-4799

April 19, 2001

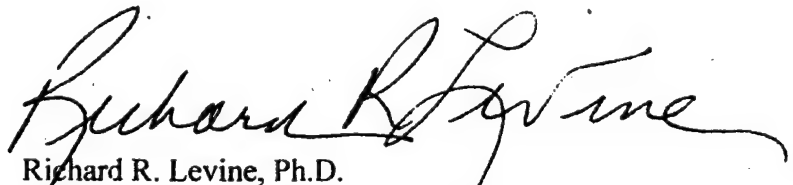
MEMORANDUM FOR CAPTS KARLA ATCHLEY & BRUCE TODD, GRADUATE
SCHOOL OF NURSING

SUBJECT: IRB Approval of Protocol T061CJ-01 For Human Subject Use

Your research protocol entitled "*Integrating Computerized Virtual Reality with Traditional Methods of Teaching Skull Anatomy*" was reviewed and approved for execution on 4/19/2001 as an exempt human research study under the provisions of 32 CFR 219.101(2)(b)(1). This approval will be reported to the full IRB scheduled to meet on 17 May 2001.

The purpose of this study is to assess the benefits of using virtual reality to supplement traditional methods of teaching anatomy in an educational setting with a convenience sample of USUHS graduate nursing students. The IRB understands that this study will use the Educational Evaluation Research Model to evaluate the effects of virtual reality teaching lessons, focusing on the identification of various bones of the human skull and structures of the human respiratory tract. The IRB further understands that subjects will be administered a questionnaire as an additional outcome measure to assess the subjective effectiveness of the teaching approach. Demographic data will also be collected; and, except for signatures on the consent form, no names or other personal identifiers will not be used in any aspect of the study or on any data collection instruments..

Please notify this office of any amendments you wish to propose and of any untoward incidents, which may occur in the conduct of this project. If you have any questions regarding human volunteers, please call me at 301-295-3303.



Richard R. Levine, Ph.D.
LTC, USA
Director, Research Programs and
Executive Secretary, IRB

cc: Director, Research Administration

USUHS FORM 3202
STUDENT and RESIDENT PHYSICIAN
RESEARCH PROTOCOL

Protocol No.: _____

Student/Resident Investigator: Bruce J. H. PhD. 1991

Department: Research Phone: _____

Project Title: Integrating Virtual Reality Technology with Traditional Plans into a Team

Research Advisor: Dr. Agazio Department: GSN

- | | | |
|-------------------------------------|---|-------------------------------------|
| <input type="checkbox"/> | Graduate Ph.D. Student | year 1 or 2 of project (Circle one) |
| <input checked="" type="checkbox"/> | Nursing Masters Student | year 1 or 2 of project (Circle one) |
| <input type="checkbox"/> | Medical Student | |
| <input type="checkbox"/> | Master or Doctorate of Public Health Student | |
| <input type="checkbox"/> | Physician Assigned for Graduate Medical Education Project Award (billeted resident physician) | |

100% Percent Effort for this project

1. Is this research project related to the advisor's active research project? Yes No
 If yes, enter the following information about the advisor's project.

Protocol Number: _____

Project Title: _____

USUHS Department: _____

2. USUHS Assurance Committees - Identify any relationship of this project with the sponsoring advisor's research protocol.

A. If human subjects are involved (including human cell lines, human tissues or fluids, surveys, databases or medical records containing information about humans), circle (1) or (2) below:

- (1) The proposed protocol is specifically covered in all relevant details by the preexisting IRB approvals of the advisor's protocol and therefore, requires no additional approvals. Attach a copy of the USUHS approval letter and, if appropriate, a copy of the approved informed consent.
- (2) The proposed protocol is not specifically covered in all relevant details by the preexisting approvals and a new completed Request for IRB Approval (USUHS Form 3204) is attached.

B. If laboratory animals are involved, circle (1) or (2) below:

- (1) The proposed protocol is specifically covered by the preexisting LARB approvals of the advisor's protocol and therefore, requires no additional approvals. Attach a copy of the USUHS LARB approval letter.
- (2) The proposed protocol is not specifically covered by the preexisting approvals and will require an addendum of the existing LARB approval or a new approval. Attach a new completed USUHS Form 3206.

- C. The use of biohazards, controlled or dangerous materials is covered as a supervised user by the existing BCD approval. If yes, submit user's and supervisor's names. Yes
 Otherwise, attach a new completed USUHS Form 3207

Appendix 2

D. The student/resident uses radiation or radioactive material as a supervised user. If Yes
yes, attach the user's and supervisor's names. **Otherwise**, attach a new completed
USUHS Form 3205.

3. BUDGET: (see USUHS Instruction 3200 for budget limitations)
Animals and Per Diem (Specify)

Supplies

Small Equipment (less than \$1,000 per item)

Other (Specify):

(May not include non-mission essential travel or secretarial/administrative support)

Total: \$

3. SUMMARY OF RESEARCH PLAN: (Attach thesis proposal or summary. The research summary should include background, hypothesis, methodology and data analysis to be used; limit to 2 pages; 12 point font)

4. The following signatures attest to the validity of the above information:

Typed Name

Signature

Date

Student/Resident Investigator:

Research Advisor:

5. Other Approvals:

Department Chair:

If: Graduate Student

Associate Dean for Graduate Education:
Michael N. Sheridan, Ph.D.

Nursing Student

Dean, Graduate School of Nursing:
Faye G. Abdellah, Ed.D. Sc.D. R.N. FAAN

Medical Student

Associate Dean for Student Affairs:
Richard M. MacDonald, M.D.

Dean, School of Medicine:
Val G. Hemming, M.D.

Physician Assigned for Graduate Medical Education

Associate Dean for Graduate Medical Education:
Howard E. Fauver, Jr., M.D.

6. In light of the above signatures, the project is approved for intramural funding.

Vice President for Research: Michael Sheridan, Ph.D.

SCHOLARLY PROJECT: COMMITTEE AGREEMENT FORM

I agree to serve on Karla Atchley & Bruce Todd's

(Student Name(s))

Scholarly Project Committee as the Chair or a Committee Member. As a committee member, I agree to meet periodically with the student(s) to provide consultation and guidance and to see how they are progressing with their Scholarly Project. The tentative title of the Scholarly Project Proposal is A Comparison of Virtual Reality and Traditional Teaching Methods.

Option Chosen: Thesis ____, Research Project submitted for Publication ☒ X

Practicum ____, Defined Project ____, # Credits 6

D. J. Rigan A.

Chair

1.31.01

Date

Oswaldo Bustos, MD

Member

1/31/01

Date

James D. Ayala

Member

31 Jan 01

Date

Thomas S. Kaufman

Member

1/31/01

Date

NOTE: Student is responsible for obtaining signatures.

Return signed form to the Research Department.

SCHOLARLY PROJECT APPROVAL FORM

TITLE OF PROJECT

INTEGRATING VIRTUAL REALITY TECHNOLOGY WITH TRADITIONAL METHODS OF TEACHING
SKULL ANATOMY

Student's Full Name

Captain K. Atchley, Captain B. Todd

APPROVED:

D. D. Riggs April 17, 2001
Chair DateRonald Buxton, MD April 17, 2001
Member DateJames H. Ayers April 17, 2001
Member DateThomas Kaufman April 17, 2001
Member Date

APPROVED:

Faye G. Abdellah 17 April 2001
Faye G. Abdellah, EdD, ScD, RN, FAAN Date
Dean

**Informed Consent Form for INTEGRATING COMPUTERIZED VIRTUAL REALITY (VR) WITH
TRADITIONAL METHODS OF TEACHING SKULL ANATOMY**

You are being invited to participate in a research project conducted by Karla Atchley and Bruce Todd, graduate students in the Uniformed Services University of the Health Sciences (USUHS), Department of Graduate School of Nursing, 4301 Jones Bridge Rd, Bethesda, MD 20814. This project is conducted under the direction of Dr. D. Rigamonti, Department of The Graduate School of Nursing.

You are invited to participate in a research study about evaluating virtual reality (VR) in the education of anatomy. The first purpose is to assess the effectiveness of VR to improve anatomical education by acting as a supplement to traditional teaching methods. This study will help to determine the benefit of supplementing traditional anatomy classroom education with the use of VR. A second purpose of the study is to assess satisfaction with VR instruction as a supplement to traditional instruction.

If you decide to participate, you will be asked to spend approximately two hours of time by taking a pre-test, attending a one hour lesson using a skull in virtual reality, and completing a post-test and satisfaction questionnaire. We will ask you to come to the office of Dr. Leon Moore located in the basement of building C of the USUHS campus to participate in this research.

There are no potential risks associated with this study. There will be no compensation for your participation. You may not benefit directly from this study, but the information we gain will be helpful in understanding the best ways to train medical and nursing personnel in the future. However, it is our hope that you will increase your understanding of skull anatomy and clinical issues from participating but no benefits are guaranteed.

If you have decided to participate in this project, please understand that your participation is voluntary and you have the right to withdraw your consent or discontinue participation at any time. You have the right to refuse to answer any question(s) for any reason.

In addition, your individual privacy will be maintained in all published and written data resulting from this study. Names will not be collected; numbers will be assigned to packets containing the examinations and satisfaction questionnaire for data collection purposes only. Forms will be stored in a secure location

This study is being funded by a federal agency which requires that data be collected in a format that may be analyzed for differences between men and women and races or ethnic groups.

If you have questions regarding your rights as a subject, any concerns regarding this project or any dissatisfaction with any aspect of this study, you may report them – confidentially, if you wish -- to the Office of Research, USUHS, 4301 Jones Bridge Rd, Bethesda, MD 20814 or by telephone to (301) 295-5134.

A signed copy of this consent form will be provided to the participant within one week.

I understand the above information and voluntarily consent to participate in the research project entitled (title of project).

Signature of Subject _____ Date _____

1. How many bones does the cranium consist of?

- A. 6.
- B. 7.
- C. 8.
- D. 9.
- E. 10.

2. On which vertebrae does the skull rest?

- A. Dens.
- B. Cervical vertebra 2.
- C. Axis.
- D. Cervical vertebra 3.
- E. Atlas.

3. When a patient fractures the dens in a deceleration injury, what clinical signs and symptoms can be seen?

- A. Normal neurological exam.
- B. Quadriplegia with respirations intact.
- C. Paraplegia.
- D. Quadriplegia with respiratory support required.
- E. Hemiplegia.

4. Which of the following bones makes up the major portion of the posterior cranial fossa?

- A. Parietal.
- B. Occipital.
- C. Sphenoid.
- D. Temporal.
- E. Ethmoid.

5. A trauma patient arrives in the ED. Physical assessment reveals fixed, dilated pupils with decerebrate posturing. CT scan shows cerebellar herniation. What region of the neuraxis would be most likely to have herniated?

- A. Cerebellar tonsils.
- B. Cerebral peduncle.
- C. Superior colliculus.
- D. Medulla.
- E. Midbrain.

6. How many cranial nerve pairs exit the posterior cranial fossa?

- A. 3.
- B. 4.
- C. 5.
- D. 6.
- E. 7.

7. If a basilar skull fracture that goes through the right hypoglossal canal, what would be the most likely clinical finding?

- A. Uvula deviation to the left.
- B. Tongue deviation to the right.
- C. Uvula deviation to the right.
- D. Tongue deviation to the left.
- E. Inability to say "ah".

8. All of the following are part of the posterior cranial fossa, EXCEPT:

- A. Foramen magnum.
- B. Jugular foramen.
- C. Optic canal.
- D. Cerebellar fossa.
- E. Facial canal.

9. The clinical landmark on the surface of the skull that overlies the bony groove for the middle meningeal artery is:

- A. Mastoid process.
- B. Mental foramen.
- C. Coronoid process.
- D. Pterion.
- E. Bregma.

10. You have a concern about a bone fragment lodged near the pterion. This is a significant area for possible hemorrhages because the _____ is located immediately underneath the pterion.

- A. Facial artery
- B. Supratrochlear vein
- C. Middle meningeal artery
- D. Angular artery
- E. External jugular vein

11. If you suspect a cerebellar tumor you might expect to find all of the following signs and symptoms, EXCEPT:

- A. Abnormal gait.
- B. Inability to perform rapid alternating movements.
- C. Inability to alternately touch examiner's fingertip.
- D. Euphoria.
- E. Abnormal posture.

12. As care provider you are expected to complete a physical exam that will evaluate cerebellar functions. Which exam would you perform?

- A. Romberg's test.
- B. Trousseau's test.
- C. Sticking the tongue out in the midline.
- D. Sensory deficit.
- E. Lhermitte's sign.

13. A space-occupying lesion of the posterior fossa, such as a hemorrhage, abscess, or tumor of the cerebellum may push the cerebellar tonsils downward into the:

- A. Jugular foramen.
- B. Hypoglossal canal.
- C. Straight sinus.
- D. Foramen magnum.
- E. Sella turcica.

14. All of the following would be expected findings in a patient with a herniation of the cerebellar tonsils, EXCEPT:

- A. Unequal or fixed pupils.
- B. Inability to look up.
- C. Deepening stupor.
- D. Irregularly-irregular breathing pattern.
- E. Impaired hearing.

15. An acoustic neurinoma (vestibular schwannoma) originates from the superior vestibular division of the eighth cranial nerve in the:

- A. External auditory canal.
- B. Lateral to the pituitary gland.
- C. Internal auditory canal.
- D. Medulla oblongata.
- E. Greater wing of the sphenoid bone.

16. Which of the following clinical signs and symptoms is consistent with a suspected acoustic neurinoma (vestibular schwannoma)?

- A. Conductive hearing loss.
- B. Impacted ear wax.
- C. Vertigo.
- D. Constricted pupils.
- E. Seizures.

17. A patient suffering from the "locked-in" syndrome would exhibit which of the following findings?

- A. Quadriplegia.
- B. Aphonia.
- C. Vertical gaze.
- D. Ability to blink.
- E. All of the above.

18. A patient presenting with Wallenberg's Syndrome will exhibit which of the following signs?

- A. Loss of pain and temperature sensation in the ipsilateral face and contralateral half of the body.
- B. Nystagmus.
- C. Ipsilateral loss of the gag reflex.
- D. Ataxia.
- E. All of the above.

19. A posterior fossa tumor (particularly in the area of the foramen magnum) can be identified by?

- A. Difficulty turning the head to the opposite side.
- B. Inability to raise the head from the supine position.
- C. Hanging shoulder.
- D. Difficulty raising the arm laterally greater than 90 degrees.
- E. All of the above.

20. Which of the clinical finding is associated with hydrocephalus in an adult?

- A. Hyperreflexic response to DTR's.
- B. Edema of the optic disks.
- C. Exophthalmos.
- D. Euphoria.
- E. None of the above.

Virtual reality in Anatomy Education Assessment Survey

This is a checklist concerning you and your feelings toward the Virtual Reality experience you've just had. Please either fill in the blank or mark the appropriate box as applicable. There are no right or wrong answers and your answers will be kept confidential.

Demographics

Age _____ Sex M / F (circle one) Class FNP / NA (circle one)

Years nursing experience _____ Educational level _____

Have you had prior virtual reality experience related to clinical anatomy?
Yes / No (circle one)

Have you had Anatomy prior to coming to USU? Yes / No (circle one)

Have you had any teaching experience related to anatomy? Yes / No
(circle one)

Please indicate the amount of computer experience you have: expert /
proficient / beginner (please circle one)

How do you feel that you learn the best?
Interactive (i.e. lab / Reading / Lecture (circle one)

	Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree
1. This experience increased my understanding of the anatomy of the skull					
2. This experience increased my understanding of the clinical implications of the stated conditions					

3. The amount of time for the lesson was sufficient?					
4. The amount of time for the exam was sufficient?					
5. I would prefer to learn this material in a lecture hall with the virtual reality simulator?					
6. I would prefer to learn this material in a lecture hall with a conventional didactic lecture?					

What did you like least about this study?

What did you like most about this study?
